

We Claim:

1. A solid state light emitting device comprising:
an active layer emitting light in response to current injected into the layer;
a first structure adjacent to the active layer, said structure trapping the light generated by the active layer; and
a second structure adjacent to the first structure extracting the light that is trapped by the first structure.
2. The device of claim 1, wherein the first structure contains substantially a single optical mode or a few lower-order optical modes, and traps the light generated in the said optical mode(s).
3. The device of claim 1, wherein the first structure comprises at least one waveguide layer.
4. The device of claim 3, wherein the at least one waveguide layer has a thickness between about 30 nm to 250 nm.
5. The device of claim 3, further comprising a transparent and conductive layer over the at least one semiconductor layer.
6. The device of claim 3, further comprising at least one cladding layer adjacent to the waveguide layer, said cladding layer having an index of refraction lower than that of the waveguide layer.
7. The device of claim 6, further comprising an Indium Tin Oxide layer over the at least one cladding layer.
8. The device of claim 7, said Indium Tin Oxide layer being electrically conductive, substantially transparent and has an index of refraction of about 1.8, said Indium Tin Oxide layer serving as an interface of the LED with air or other media.

9. The device of claim 7, wherein the Indium Tin Oxide layer has a thickness in a range of about 30 to 300 nm.

10. The device of claim 7, wherein the Indium Tin Oxide layer has a thickness of about 89 nm for 640 nm optical emission by the LED, or about 65 nm for 470 nm optical emission by the LED.

11. The device of claim 7, wherein the Indium Tin Oxide layer has a thickness substantially equal to $\lambda / (4 n_{\text{ito}})$, where λ is wavelength of light generated by the active layer, and n_{ito} is the index of refraction of the Indium Tin Oxide layer.

12. The device of claim 7, further comprising a metal layer between the Indium Tin Oxide layer and the active layer.

13. The device of claim 1, wherein the second structure comprises photonic crystal cells.

14. The device of claim 13, wherein the photonic crystal cells comprise at least one array of holes in the device.

15. The device of claim 14, said second structure comprising at least one layer, wherein the photonic crystal cells comprise at least one array of holes in said at least one layer.

16. The device of claim 14, said at least one array of holes forming a two dimensional array.

17. The device of claim 16, further comprising at least one electrode layer through which current is injected into the active layer.

18. The device of claim 17, said at least one electrode layer having a grid-shaped pattern, or a pattern with hexagonal openings therein.

19. The device of claim 18, said second structure comprising a plurality of arrays of holes, each array located so that it is enclosed by a grid cell or exposed through a hexagonal opening in said at least one patterned electrode layer, wherein each array extracts light from the first structure and causes the extracted light to escape through a corresponding hexagonal opening of the electrode layer, or an area bounded by adjacent strips of a grid-shaped electrode layer.

20. The device of claim 18, said at least one electrode layer having the pattern with hexagonal openings therein, wherein a width of a portion of the electrode layer between two adjacent hexagonal openings is about $\sqrt{3}$ times a length of one side of the hexagonal openings.

21. The device of claim 18, said array of holes of the photonic crystal cells forming a triangular pattern, each photonic crystal cell having a hexagonal shape within each of the hexagonal openings in the electrode.

22. The device of claim 18, said electrode layer comprising elongated strips forming a network, wherein a width of the strips is in a range of about 1 to 100 μm .

23. The device of claim 17, said LED comprising a plurality of semiconductor chips, said at least one electrode layer comprising a network on each chip enclosing at least one of the photonic crystal cells.

24. The device of claim 23, said network comprising a plurality of grid cells, each grid cell enclosing a photonic crystal cell.

25. The device of claim 24, said grid cells being square or rectangular in shape.

26. The device of claim 24, each photonic crystal cell within a grid cell having a dimension in a range of about 1 to 100 μm .

27. The device of claim 17, wherein there is no hole abutting and underneath the at least one electrode layer.

28. The device of claim 16, said holes forming a triangular, square or rectangular array.

29. The device of claim 14, wherein a lattice constant of said at least one array of holes is in a range of about 80 to 500 nm, and the holes have diameters in the range of about 50nm to 300 nm.

30. The device of claim 13, each photonic crystal cell having a dimension in a range of about 5 to 100 μm .

31. The device of claim 1, further comprising a substrate layer.

32. The device of claim 31, wherein the substrate layer has a band gap that is wider than that of the active layer, so that light emitted by the active layer is not absorbed significantly by the substrate layer, and so that light emitted by the active layer is emitted from both sides of the LED.

33. The device of claim 31, wherein the substrate layer is separated from the active layer by the first and second structures.

34. A method for making a solid state light emitting device, comprising:
providing an semiconductor body, said body having an active layer that emits light when electrical current is injected into the layer, and at least another layer adjacent to the active layer; and

forming at least one array of holes in said at least another layer to provide photonic crystal cells, wherein said forming includes imprinting a pattern having surface features with dimensions of less than about 300 nm on a layer on the body.

35. The method of claim 34, wherein said forming comprises providing a resist layer on the body, imprinting a pattern of indentations onto the resist layer, and etching away a portion of the resist layer to expose surface areas of the body commensurate with the pattern of indentations.

36. The method of claim 35, wherein said imprinting is performed by means of a positive mold with protruding nanometer scale pillars.

37. The method of claim 36, wherein the pillars in the mold are cylindrical in shape.

38. The method of claim 36, said imprinting further comprising making a negative mold, and then using the negative mold to replicate positive molds.

39. A method for emitting light, comprising:
injecting electrical current into an active layer, causing the layer to emit light in response to the current injected into the layer;
trapping the light generated by the active layer by means of a structure; and
extracting the light that is trapped by the structure.

40. The method of claim 39, wherein the light trapped in the structure is substantially in one or a few lower-order modes.

41. The method of claim 39, wherein the trapping is by means of a structure comprises at least one waveguide layer.

42. The method of claim 39, wherein the extracting is performed by means of a photonic crystal structure.

43. The method of claim 42, wherein the injecting injects current along paths away from the photonic crystal structure.

44. The method of claim 42, wherein the injecting is by means of an electrode network having a plurality of cells, each network cell enclosing a corresponding photonic crystal cell.